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EDITORIAL COMMENT

Percutaneous Revascularization of Coronary Chronic Total Occlusions

The New Era Begins*

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The best available current evidence suggests that the hard end point outcomes of patients with coronary chronic total occlusion (CTO) are no different from those of patients with nonoccluded stenoses. The reassurance that these lesions are benign because they are "well collateralized" or "not at risk for closure" is not well-founded and contradictory to a large body of evidence implying the opposite (1–6). Patients with attempted CTO percutaneous coronary intervention (PCI) that is successful have improved survival compared with those with unsuccessful attempts and persistently closed arteries. In addition, successful PCI of CTO is associated with improved quality of life, reduced ischemia, and improved regional and global left ventricular function (3,7–9). These benefits are predicated on persistent patency of the PCI segment.

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The concept that "stable" coronary disease (a definition crudely derived from patient symptomatic status) is a uniform phenotype and has predictable outcomes continues to be challenged in the presence of data that suggest coronary disease is not intrinsically stable but rather represents a risk continuum (10,11). In the highest-risk patients with multivessel coronary disease, incomplete revascularization with and without presence of CTO seems to have poorer survival compared with patients who can be completely revascularized (12–14). One can only logically conclude that CTO is not a benign entity.

Differential outcomes of patients with single-vessel coronary disease can be segregated by the degree of ischemic burden, which might help better discriminate those patients who could derive survival benefit from revascularization (10,11). Considering this, is seems reasonable to construct a model to triage patients for revascularization of occluded arteries on the basis of ischemic risk assessment (Fig. 1), symptomatic status, and attributable impairment of left ventricular function. This ischemic risk model can help reconcile apparent conflicting recent data from the OAT (Occluded Artery Trial), which enrolled patients with predominantly nonchronically occluded arteries (e.g., not CTO by conventional definition), after recent myocardial infarction with minimal residual ischemia and symptoms (15). Low-risk patients might be safely deferred, but higher-risk patients with ischemic burden or symptoms should be considered for revascularization. This model is strongly supported by the COURAGE (Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation) trial's nuclear substudy (11). It is likely the magnitude of benefit is underestimated, given that the COURAGE trial required coronary angiography before enrollment and therefore might have excluded higher-risk patients.

The CTO PCI attempt rates of patients identified are relatively low (approximately 11% to 13%) and seem unchanged over time during recent years (8). It is very likely that—when attributable symptoms of chest pain, heart failure/dyspnea, and/or fatigue; left ventricular dysfunction; and the risk continuum model (Fig. 1) are considered—we are dramatically under-revascularizing these patients in terms of attempt rates in patients with appropriate indications.

A major reason for this is related to the technical complexity and poor success rates for CTO PCI procedures (approximately <50% to 70% in "less complex" CTO lesions) and concerns for adverse acute procedure-related complications. Coronary bypass is seen as an alternative for patients with multivessel disease, but the widely held notion that this surgical procedure can uniformly provide successful bypass grafting to the CTO segment or offer completed revascularization in this patient subset has been refuted. The initial reports from the randomized SYNTAX (SYNergy Between PCI With TAXUS and Cardiac Surgery) clinical trial CTO subset suggest similar challenges are encountered by our surgical colleagues with successful bypass grafting of the CTO segment in only 69% and complete revascularization in 49.6% in this complex patient/lesion subset (16). Stand-alone medical therapy as an alternative does not reduce ischemic burden and might be less preferable in patients at highest risk.

The paper by Morino et al. (17) in this issue of *JACC: Cardiovascular Interventions* details a contemporary multicenter experience from 498 patients having CTO PCI in the J-CTO registry (multicenter CTO Registry in Japan) from April 2006 to November 2007. Multiple operators and institutions were capable of achieving high technical success

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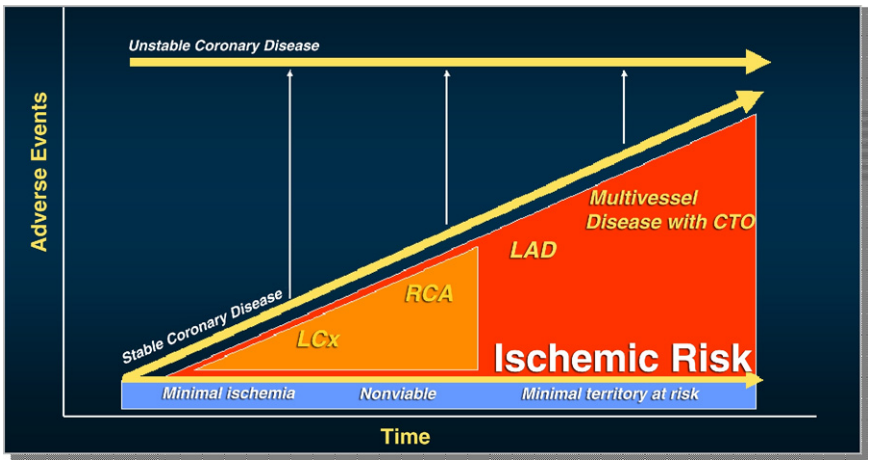

Figure 1. Ischemic Risk Model for Coronary Disease With Predictable/Stable Symptoms: A Decision Matrix for CTO Revascularization

Current outcomes data suggest that adverse events for coronary disease can be risk-predicted by coronary disease burden (e.g., phenotyped multivessel coronary disease) and magnitude and degree of ischemia. In this revascularization decision matrix model, coronary disease is not assumed to be intrinsically stable on the basis of predictable symptoms but rather as a risk continuum. In this model, patients at higher risk are more likely to destabilize and transition to acute syndromes, myocardial infarction, and death. The highest-risk patients seem to have the greatest magnitude of benefit from revascularization. Benefits from revascularization are presumed to be greatest for patients with multivessel disease with chronic total occlusion (CTO) and left anterior descending coronary artery (LAD) CTO, followed by single-vessel right coronary artery (RCA) or left circumflex artery (LCx) CTO with high ischemic burden. This risk continuum might represent a framework to substratify (in addition to symptomatic status) and determine revascularization, including that for CTO, for patients with nonacute coronary artery disease.

(86.6%) with low rates of cardiac death (0.2%) and significant myocardial infarction (2.1%) with contemporary and advanced technical approaches, including contralateral injection, parallel wiring, intravascular ultrasound guidance, and retrograde techniques (overall retrograde attempt included 25.7% of procedures). The technical success and in-hospital outcomes compare very favorably and are consistent with similar contemporary experiences and limited reports from the U.S. (approximately 90% technical success, approximately 2% major adverse cardiac events) and Europe (approximately 83.4% technical success, approximately 2% major adverse cardiac events) in this timeframe (18,19). The J-CTO investigators did not discuss the operator's and institution's experience level in the present report, but these are presumed to be quite high, and therefore we do not know the immediate applicability and reproducibility of these data to less experienced operators in Japan and elsewhere in the world. However, cumulatively, these reports demonstrate a potential pathway for high technical success with low adverse event profile in widely disparate clinical and cultural environments, predicated on innovative techniques pioneered in Japan and now continuing to be iterated throughout the world.

Yet, many coronary arteries causing patients symptoms and harm remain closed. How can these techniques and results best be translated in a broad manner to better impact public health?

First, identify patients appropriate for the procedure. Patients with symptoms or attributable left ventricular impairment in whom the risk-benefit estimate justifies the procedure should be considered for revascularization. In patients (young or young elderly) with an otherwise long life expectancy, completed revascularization for multivessel disease, left anterior descending coronary artery CTO, and non-left anterior descending coronary artery CTO with large ischemic burden should be considered, irrespective of symptomatic status. Patients with minimal symptoms and ischemia generally should be deferred.

Second, a broader access to operators performing CTO PCI is needed. In the absence of disruptive technologic advances, this would be best served in a multitiered system where "simple" CTO PCI can be performed by less-experienced operators and prior PCI failures or more complex lesion/clinical populations be referred to a dedicated "CTO specialist." It is clear that the safety and effectiveness of the more complex strategies are related to operator volume and ascension of a learning curve (18). Adequate training programs and continuing medical education will need to continue to be developed to broaden the pool of CTO operators.

Third, very few health care and reimbursement systems value the time and resource use that can be required for a successful CTO PCI program. Currently, data are lacking on cost-effectiveness, and current health care systems in various countries impede rather than encourage CTO PCI

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in favor of time- and resource-limited procedures. Adjustments in reimbursement models aligned with CTO PCI could improve patient access to these procedures and benefits.

The J-CTO investigators and other early leaders from Japan should be congratulated and acknowledged for technique innovations to improve the safety and effectiveness of CTO PCI, which now is slowly but surely being reproduced and iterated elsewhere in the world. On the basis of the collective emerging data, it seems that success rates of 80% to 90% with the contemporary strategies and techniques are consistently achievable in experienced hands with a safety profile comparable to standard risk-adjusted PCI. The justifications and attitude to avoid CTO revascularization on the basis of real or perceived poor success rates, unclear patient benefits, adverse outcomes, time/resource use, or need for coronary bypass surgery are becoming part of our collective past. As these advances are disseminated, the new era of CTO revascularization in patients with symptoms and/or ischemic burden begins in which the question is not "Why should we open the occluded vessel?" but "What is the justification to leave the vessel closed?"

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